ADMINISTRATIVE INFORMATION

1. Project Name:
Fracture Toughness and Strength in a New Class of Bainitic Chromium-Tungsten Steels

2. Lead Organization:

(1) Department of Mechanical Engineering, University of Pittsburgh,
3700 O'Hara St. Pittsburgh, PA 15261

(2) Materials Processing Group, Metals and Ceramics Division
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3. Principal Investigator:

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4. Project Partners:

- Nooter Fabrication Services Inc., **In-Kind**, provided technical requirement and review for the processing and application of the materials as well as welding process technology.
  Contact: Maan Jawad,
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5. Date Project Initiated: 10/1/2001

6. Expected Completion Date: 09/30/2004

PROJECT RATIONALE AND STRATEGY

7. Project Objective:
The goal of this project is to provide an understanding the relationship among composition, microstructure and heat treatment to achieve both high strength and fracture toughness, and guide the development of a new class of Fe-3Cr-W(V) ferritic steels for chemical process applications. The ultimate goal is to reduce the weight of large pressure vessel and associated components by approximately 25% and eliminate the need for PWHTs with estimated energy savings.

8. Technical Barrier(s) Being Addressed:
There are no significant barriers encountered so far in investigation of composition, microstructure, heat treatment and mechanical properties relationship of the new bainite 3Cr-3WV(Ta) steels.

9. Project Pathway

The project partners recognized that it is significant to investigate the effects of aging on the microstructure and fracture toughness of the steels from the point of view of industrial applications. We have investigated the effect of aging based on the results that had been obtained.

10. Critical Technical Metrics:

Baseline Metrics:
- The yield strength of conventional Cr-Mo ferritic steels (2.25Cr-1Mo) is approximately 645 MPa under normalized and tempered condition (tempering temperature is 700°C).
- The yield strength of conventional Cr-W martensitic steel (such as 9Cr-2WV) is 823 MPa and 645 MPa at tempering temperature of 700°C and 750°C, respectively. However, PWHTs is needed.

Project Metrics:
- The new 3Cr-3WVTa bainitic steel has higher shtrength than or as good as Cr-W martensitic steel, but PWHTs can be eliminated.
- Understanding the relationship among composition, microstructure and heat treatment to achieve both high strength and high fracture toughness of the new 3Cr-3WVTa bainitic steel.

PROJECT PLANS AND PROGRESS

11. Past Accomplishments:

- High strength and toughness steels of 3Cr3WV have been developed at the Oak Ridge National Laboratory (ORNL).
- The microstructures of the 3Cr-3WV and 3Cr-3WVTa steels under normalized and normalized-and-tempered conditions have been examined by optical microscope (OM) and transmission electron microscope (TEM)
- . Carbides, especially fine TaC particles, precipitated in the steel have been extensively examined by TEM with extraction replicas samples.
- Tensile test and fracture toughness (K_{IC}) test have been carried out.
- Aging of the steels at 550°C for up to 1000 h has been performed, and the effects of aging on the microstructure and fracture toughness have been investigated.
- Effects of fine carbides in the steels on strength and fracture toughness of the steels have been studied.
- Carbides precipitated during aging have been investigated by TEM using extraction replicas samples.
- A new bainite Fe3Cr alloy steel, which is a modification on the basis of 3Cr-3WV steel, has been developed in Oak Ridge National Laboratory.
- The microstructures of the new bainitic Fe3Cr alloy steels under normalized and normalized-and-tempered conditions have been examined.
- Fracture toughness K_{1C} of the new Fe3Cr steel will be measured and the fractographs of the Fe3Cr steels have been observed by SEM.
- The microstructures of welded joint of the 3Cr-3VW(Ta) steels and Hardness distribution across the weld line have been examined.

12. Future Plans:

- Fracture toughness K_{1C} of weld metal and HAZ of welded joint of the 3Cr-3VW(Ta) steels will be determined.
- The effects of PWHT on the microstructure, hardness and fracture toughness K_{1C} of

the welded joint of 3Cr-3VW(Ta) steels will be studied.

13. Project Changes:

Under the current program there have been no changes in the project direction or timetable.

14. Commercialization Potential, Plans, and Activities:

- The results will provide an understanding of the relationship among composition, microstructure and heat treatment to achieve both high strength and fracture toughness, and guide the development of a new class of Fe-3Cr-W(V) ferritic steels.
- High strength and fracture toughness 3Cr-3WV(Ta) steels can be used in chemical engineering equipments, large pressure vessel and associated components.
- The weight of steels for construction of those components will be expected to be reduced by approximately 25% by suing new 3Cr-3WV(Ta) steels.
- the PWHTs of components can be eliminated with extensive energy savings.

15. Patents, publications, presentations:

(1) Fine Carbides Strengthened 3Cr-3WVTa Bainite Steels,
Zheng Chen, Zhi-wei Shan, N. Q. Wu, V. K. Sikka, Mingjian Hua and Scott X. Mao,.
(***Metallurgical and Materials Transactions A***, Vol. 35A, 2004: 1281)

(2) Fracture Toughness and Strength in a New Class of Bainitic Chromium-Tungsten Steels,
Mao, S. & V. Sikka, Industrial Materials for Future (IMF) Program Review Meeting on , Albuquerque, NM 87102, July 8-10, 2002.

(3) Effect of aging on microstructure and fracture toughness of 3Cr-3VW(Ta) steels
Zheng Chen, Zhi-wei Shan, N. Q. Wu, V. K. Sikka, and Scott X. Mao,
(will be submitted to ***J. Mater. Sci***.)